Transmission Line Analysis

- Propagating electric field

Space factor

$$E_X = E_{0X} \cos(wt - kz)$$

Time factor

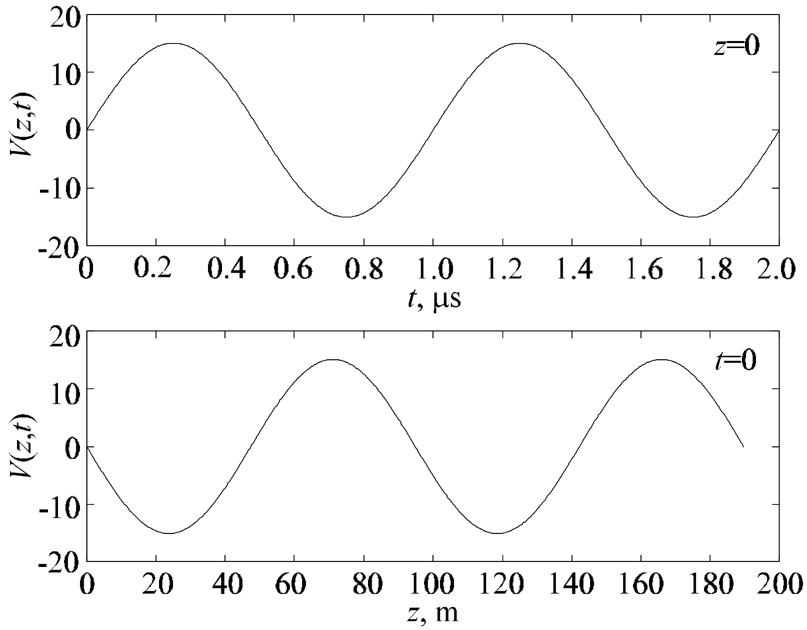
- Phase velocity

$$v_p = l \ f = \frac{1}{\sqrt{em}} = \frac{c}{\sqrt{e_r}}$$

- Traveling voltage wave

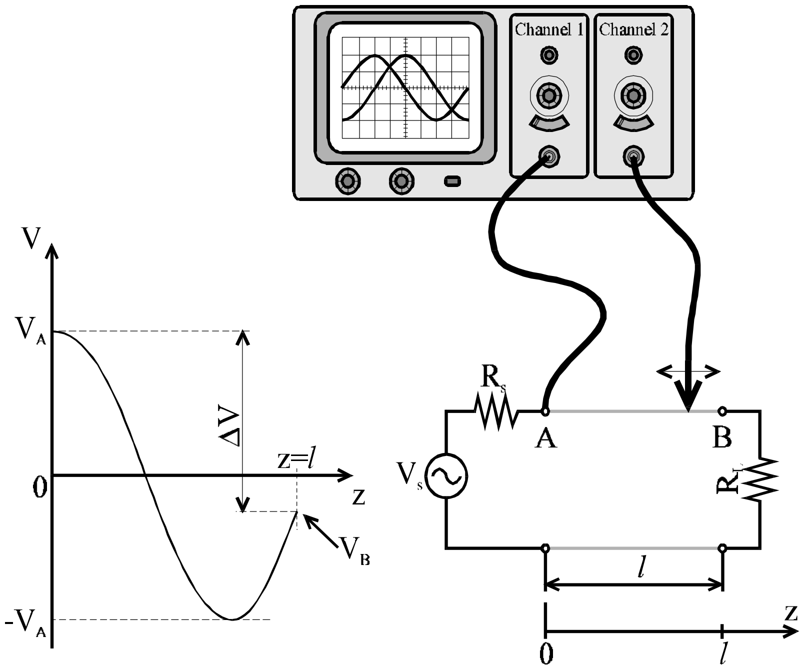
$$V(z,t) = E_{0X} \frac{\sin(wt - kz)}{k}$$

High frequency implies spatial voltage distribution



- Voltage has a time and space behavior
- Space is neglected for low frequency applications
- For RF there can be a large spatial variation

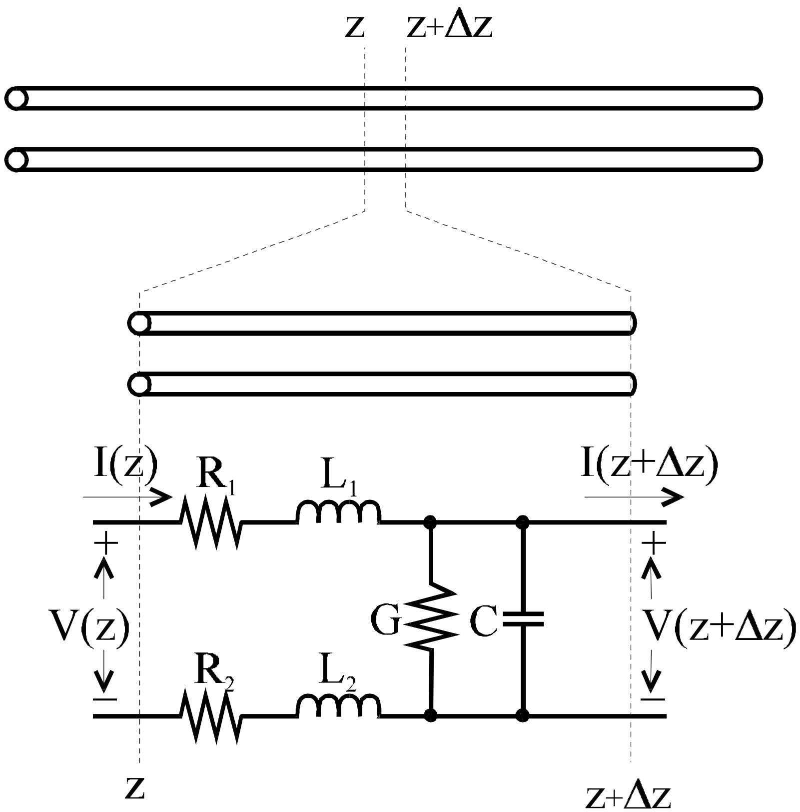
Generic way to measure spatial voltage variations



- For low frequency (1MHz) Kirchhoff's laws apply

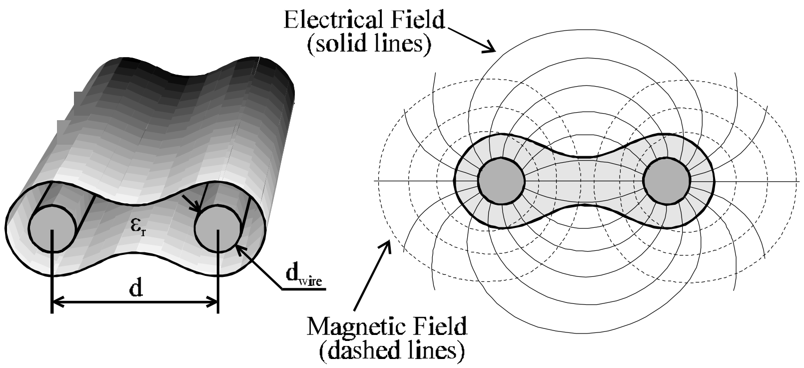
- For high frequency (1GHz) Kirchhoff's laws do **not apply** anymore

Kirchhoff's laws on a microscopic level



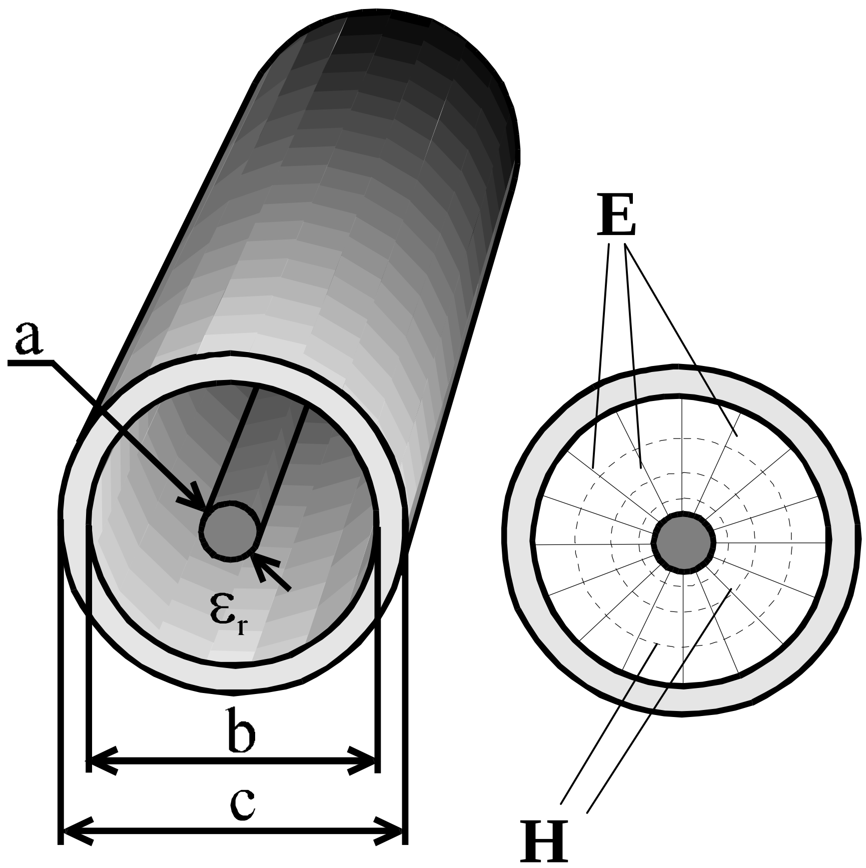
- Over a differential section we can again use basic circuit theory
- Model takes into account line losses and dielectric losses
- Ideal line involves only L and C

Example of transmission line: **Two-wire line**



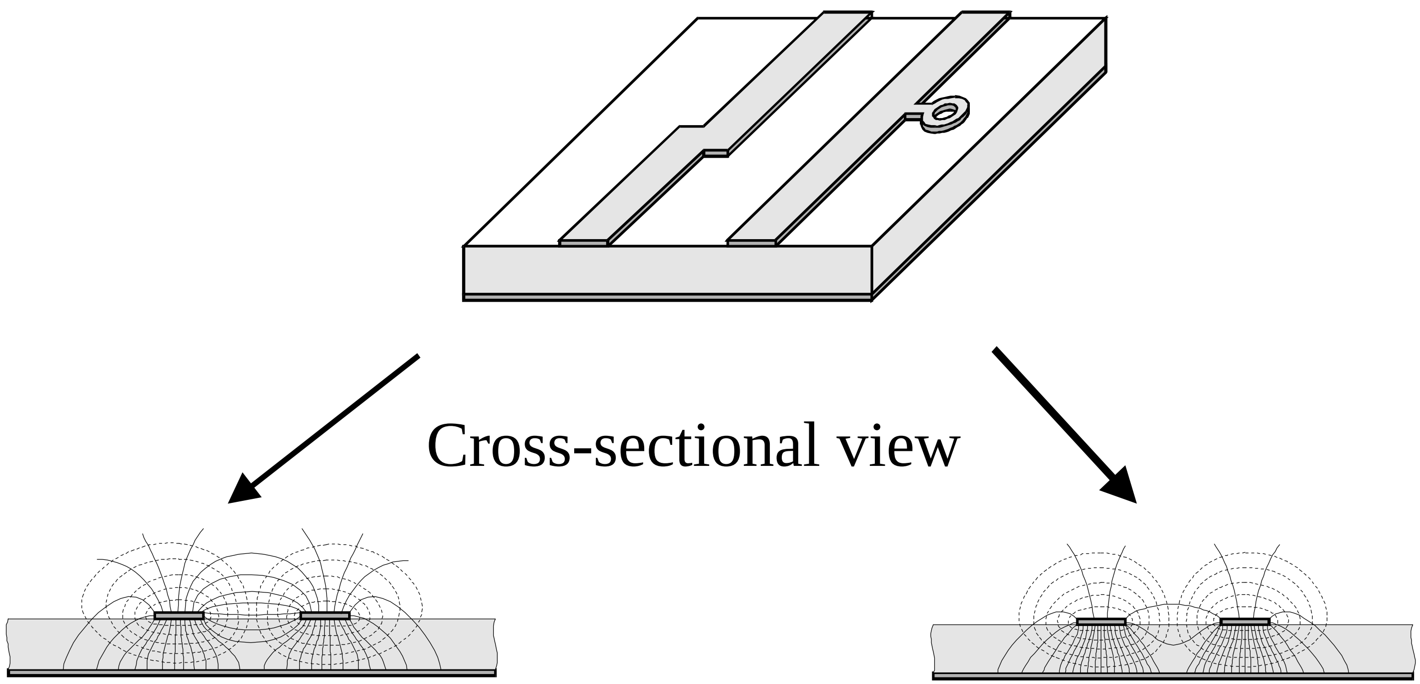
- Alternating electric field between conductors
- alternating magnetic field surrounding conductors
- dielectric medium tends to confine field inside material

Example of transmission line: **Coaxial cable**



- Electric field is completely contained within both conductors
- Perfect shielding of magnetic field
- TEM modes up to a certain cut-off frequency

Example of transmission line: Microstip line

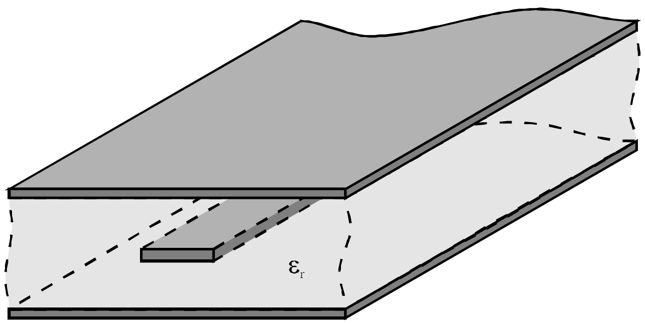


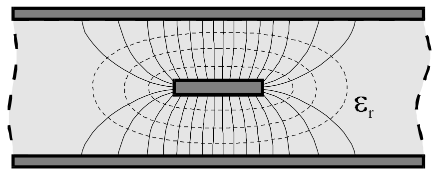
Low dielectric medium

High dielectric medium

Triple-layer transmission line

Conductor is completely shielded between two ground planes





Cross-sectional view